PAT December, 2020; 16 (2): 7-12 ISSN: 0794-5213
Online copy available at www.patnsukjournal.net/currentissue
Publication of Nasarawa State University, Keffi

Dry Matter Production of Soybean (*Glycine max. L. Merrill*) As Influenced by Phosphorus Fertilizer and Varieties

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Abstract
Field experiments were conducted during the rainy seasons of 2018 and 2019 Cropping seasons at the Teaching and Research Farm of the Faculty of Agriculture, Nasarawa State University, Keffi-Lafia Campus to study the effect of phosphorus fertilizer (P) on dry matter production and varietal differences in soybeans. Treatments consisted of four levels of phosphorus fertilizer (0, 13, 26 and 39 kg ha^{-1}) and six varieties of soybean (TGX 1985-10F, TGX 1987-10F, TGX 1448-2E, TGX 1987-62F, TGX 1989-19F and TGX 1835-10E). The treatment combinations were laid out in a Randomized Complete Block Design (RCBD) in triplicates. Results obtained in both years indicated that dry matter production increased with increase of P application significantly at (P<0.05) and 39 kg P ha^{-1} produced significantly (P<0.05) the highest total dry matter (TDM), relative growth rate (RGR) and crop growth rate (CGR) plant^{-1} at all growing stages. Varietal differences affect dry matter production with TGX 989-19F variety recorded consistently higher TDM, RGR and CGR plant^{-1} of soybean compared to other varieties tested in both cropping years.

***Keywords**: Phosphorus fertilizer, Soybeans Varietal differences, Dry matter, Relative growth rate, Crop growth rate*

Introduction

Soybean (Glycinemax. L. merrill) is a species of legumes belonging to the fabaceae family. It is rich in protein, oil and carbohydrates (Atli, 2019). It has the highest amount of protein among the legumes (Mohadese, 2014). Soybean also improves soil fertility by adding nitrogen from the atmosphere into plant useable forms through symbiosis with rhizobia in the soils (Dugje, 2009). Fertilizer application is one of the primary methods for improving soil nutrients availability to plants. Phosphorus (P) is a major essential nutrient required by plants for growth and reproduction (MOSAIC, 2019). The roles of P in legumes development are to increase plant growth such as number of branches, number of leaves, root proliferation, enhanced nodulation activity and weight of plant (Cassman *et al.,* 1980; Konno *et al.,* 1990; Chaudhary and Fujita, 1998). Phosphorus deficiency in legumes reduces leaf area, number of branches, number of leaves and weight (Chaudhary *et al.,* 2008). Phosphorus fertilization can change rates of plant growth, maturity time, size of plant parts and weight in legumes (Kakiuchi, 2015). Phosphorus influences dry matter production such as relative growth rate, crop growth rate and net assimilation rate per plant (Abbasi *et al.,* 2012), and seed production in soybean (Kakiuchi and Kobata, 2006; De bruin and Pederson, 2009). However, there are few research works on the effects of phosphorus on dry matter production and its varietal differences in soybeans. Therefore, the objective of this present study is to investigate the effects of phosphorus on dry matter production and varietal differences in soybeans.

Materials and methods

The experiments were conducted at the Teaching and Research Farm of the Faculty of Agriculture, Shabu-Lafia Campus, Nasarawa State University Keffi, Nigeria, during the

2018 and 2019 Cropping seasons. The site is located on Latitude 08.33^0N and Longitude 08.33^0E and falls within the Southern Guinea Savanna zone of Nigeria (Jayeoba, 2013). The experiments consisted of four levels of phosphorus (0, 13, 26 and 39 $kgPha^{-1}$) in a form of single super phosphate and six different varieties of soybean (TGX 1985-10F, TGX 1987-10F, TGX 1448-2E, TGX 1987-62F, TGX 1989-19F and TGX 1835-10E). The treatment combinations were laid out in a Randomized Complete Block Design (RCBD) with three replications. The four levels of phosphorus were applied according to treatment combinations and incorporated into the ridges, respectively during land preparation. Three soybean seeds per hole were sown at a recommended planting spacing of 75cm between rows and 5cm between plants. Thinning of some seedlings was carryout 15 days after sowing (DAS). Hoe weeding was done at 3, 6, and 9 weeks after sowing (WAS) to keep the plots weed free. Five randomly selected tagged plants in each plot were used for periodic observation during the crop growth periods at 4, 6, 8, 10 and 12 WAS. Data collected were subjected to analysis of variance and mean separated by standard error (SE ±) at 5% level probability using SAS statistical package. The following parameters taken were: Total dry matterper plant was obtained from 2 plants cut from the base of the stem, detached into leaves and stems, then oven dried at temperature of 70^0c for 48 hours. The dried samples were weighed using a sensitive weighing scale and weight (g) recorded at 4, 6, 8, 10 and 12 WAS. Growth analysis was carried out from the total dry matter harvested:

Relative growth rate (RGR) was determined as described by Radford (1967).

$$RGR = \frac{LnW_2 - LnW_1}{T_2 - T_1} \quad g/g/wk$$

Crop growth rate (CGR) was determined as described by Radford (1967).

$$CGR = \frac{W_2 - W_1}{T_2 - T_1} \times \frac{1}{G} g/m^2/wk$$

Where W_1 and W_2 are total dry weight at time T_1 and T_2 in weeks respectively, and G is the land area.

Results and Discussion

Total dry matter (TDM)

In both 2018 and 2019 cropping years, at all sampling periods, each increase in the rate of phosphorus significantly($P<0.05$) increased TDM per plant of soybean (Table 1). This attributed to the fact that soybean plant adequately utilized and stored phosphorus for their growth and development and hence, attained highest TDM plant [1]. In 2018, at 4WAS, TGX 1987-10F, TGX 1987-62F and TGX 1989-19F produced similar TDM per plant of soybean but significantly ($P<0.05$) higher compared to other varieties. In 2018 season, at 6, 8, 10 and 12 WAS and at all sampling periods in 2019 season, TGX 1989-19F recorded significantly higher TDM per soybean plant respectively, followed by TGX 1987-62F compared to all other varieties. The higher values of TDM $plant^{-1}$ in respond to phosphorus fertilization and variety is a reflection of growth and yield in soybean. These findings are in line with the work of Malik *et al.,* (2006), who found that 30-45 kg ha^{-1} of phosphorus applied enhanced significantly total dry matter $plant^{-1}$ of soybean significantly thereby resulting in higher seed yield of 1550-1680 kg ha^{-1}.

Table 1: Effects of Phosphorus and Variety on the Total Dry Matter of Soybean at 4, 6, 8, 10 and 12 WAS at Lafia during 2018 and 2019 cropping seasons.

	2018 WAS					2019 WAS				
Treatment	**4**	**6**	**8**	**10**	**12**	**4**	**6**	**8**	**10**	**12**
Phosphorus (kg ha^{-1})										
0	0.9d	2.7d	15.0d	34.2d	38.5d	0.6d	3.3d	12.7d	33.7d	36.5d
13	1.1c	3.4c	16.9c	33.1c	38.7c	1.2c	3.7c	13.6c	34.3c	41.6c
26	1.6b	5.7b	23.5b	49.4b	50.9b	1.5b	4.5b	19.9b	45.7b	49.6b
39	1.7a	6.1a	31.8a	54.4a	55.1a	1.7a	6.5a	35.7a	46.6a	51.0a
SE ±(0.05)	0.07	0.11	0.19	0.22	0.28	0.04	0.10	0.18	0.16	0.22
Variety										
TGX 1985-10F	1.0b	5.2d	17.1d	37.0d	39.4c	0.8e	4.0d	18.9e	37.8d	39.1d
TGX 1987-10F	1.5a	54.c	21.9c	49.3c	52.0b	1.2c	4.7c	20.6c	43.0c	44.9c
TGX 1448-2E	1.0b	3.3e	14.7f	34.7f	39.0d	1.0d	3.5e	19.3d	43.2c	44.7c
TGX 1987-62F	1.6a	5.8b	25.1b	50.4b	52.2b	1.3b	5.4b	31.2b	46.2b	47.7b
TGX 1989-19F	1.6a	6.2a	32.1a	54.3a	56.2a	1.5a	6.0a	35.1a	48.9a	51.1a
TGX 1835-10E	0.8c	2.8f	16.3e	36.0e	38.5e	0.5f	3.0f	16.3f	36.1e	37.4e
SE ±(0.05)	0.10	0.13	0.24	0.18	0.22	0.04	0.12	0.20	0.16	0.26

Means of different letter(s) in each column of treatment group are significant at 5% level of probability.

Relative growth rate (RGR)

At all sampling periods, in both years, application of 39 kg P ha^{-1} produced significantly ($P<0.05$) higher relative growth rate per soybean plant. However, 26 kg P ha^{-1} treatment produced similar relative growth rate at 6-4 and 10-8 WAS in 2019 (Table 2). The higher RGR obtain at 39 kg ha^{-1} of phosphorus could be attributed to the fact that highest RGR plant^{-1} were obtained at that rate while the lowest RGR produced by the control plots could be attributed to the fact that the lowest RGR were obtained at that rate also Similarly, in 2018, at all sampling periods, TGX 1989-19F recorded significantly($P<0.05$) higher RGR per plant, followed by TGX 1987-62F compared to other varieties while in 2019, at 6-4 and 12-10 WAS, TGX 1987-62F and TGX 1987-10F produced similar RGR per soybean plant and significantly higher than other varieties. At 8-6 and 10-8 WAS, TGX 1989-19F consistently produced significantly higher (RGR) compared to other varieties in both cropping seasons. The higher RGR values for TGX 1989-19F variety in both years, is an indication that the variety respond to phosphorus fertilization is more efficient at all growing stages than other varieties.

Table 2: Effects of Phosphorus and Variety on the Relative Growth Rate of Soybean at 4, 6, 8, 10 and 12 WAS at Lafia during 2018 and 2019 cropping seasons.

	2018				2019			
	WAS				WAS			
Treatment	**6-4**	**8-6**	**10-8**	**12-10**	**6-4**	**8-6**	**10-8**	**12-10**
Phosphorus (kg ha^{-1})								
0	0.3^{d}	0.7^{d}	0.8^{c}	0.9^{c}	0.3^{c}	0.7^{b}	0.7^{b}	0.8^{c}
13	0.4^{c}	1.0^{b}	1.1^{b}	1.2^{b}	0.4^{b}	0.7^{b}	0.8^{a}	0.8^{c}
26	0.6^{b}	0.8^{c}	1.1^{b}	1.2^{b}	0.6^{a}	0.7^{b}	1.1^{a}	1.1^{b}
39	0.7^{a}	1.1^{a}	1.3^{a}	1.4^{a}	0.6^{a}	0.8^{a}	1.1^{a}	1.5^{a}
SE ±(0.05)	0.02	0.02	0.01	0.13	0.01	0.01	0.01	0.01
Variety								
TGX 1985-10F	0.4^{c}	0.7^{d}	0.8^{c}	0.8^{e}	0.4^{c}	0.6^{d}	0.8^{c}	0.8^{b}
TGX 1987-10F	0.5^{b}	0.8^{c}	1.1^{b}	1.2^{c}	0.5^{b}	0.8^{b}	0.9^{b}	1.0^{a}
TGX 1448-2E	0.4^{c}	0.7^{d}	0.9^{c}	1.0^{d}	0.5^{b}	0.7^{c}	0.8^{c}	0.8^{b}
TGX 1987-62F	0.5^{b}	1.0^{b}	1.2^{b}	1.4^{b}	0.6^{a}	0.8^{b}	0.9^{b}	1.0^{a}
TGX 1989-19F	0.7^{a}	1.4^{a}	1.6^{a}	1.9^{a}	0.5^{b}	0.9^{a}	1.0^{a}	0.8^{a}
TGX 1835-10E	0.4^{c}	0.7^{d}	0.8^{c}	0.8^{e}	0.4^{c}	0.6^{d}	0.6^{d}	0.7^{c}
SE ±(0.05)	0..02	0.02	0.01	0.02	0.01	0.01	0.01	0.02

Means of different letter(s) in each column of treatment group are significant at 5% level of probability.

Crop growth rate (CGR)

Table 3 shows the effect of phosphorus and variety on the crop growth rate of soybean plant during 2018 and 2019 cropping years. The results indicated that at all sampling periods, each increase in the rate of applied phosphorus significantly ($P<0.05$) increased CGR per plant of soybean in both cropping years. This indicates the efficient and positive role of phosphorus on CGR plant^{-1} of soybean. This findings was supported by the work of Abbasi *et al.,*(2012), who reported that increased in phosphorus application significantly enhanced TDM and CGR plant^{-1} of soybean.

In 2018, at 6-4 and 10-8 WAS, TGX 1989-19F, TGX 1987-62F and TGX 1987-10F produced statistically similar CGR per plant but significantly ($P<0.05$) higher compared to other varieties. At 8-6 and 12-10 WAS, TGX 1989-19F recorded the highest CGR per plant compared with other varieties.

In 2019, at all sampling periods, TGX 1989-19F produced significantly higher CGR per plant compared with other varieties followed by TGX 1989-62F and TGX 1989-10F which produced similar CGR per plant of soybean. The outstanding performance of TGX 1989-62F and TGX 1989-10F on total dry matter production could be due to the genotypic differences as suggested by Umeh *et al.,* (2011), as the growth of soybean differed significantly in all varieties.

Table 3: Effects of Phosphorus and Variety on the Crop Growth Rate of Soybean at 4, 6, 8, 10 and 12 WAS at Lafia during 2018 and 2019 cropping seasons.

	2018				2019			
	WAS				WAS			
Treatment	**6-4**	**8-6**	**10-8**	**12-10**	**6-4**	**8-6**	**10-8**	**12-10**
Phosphorus (kg ha^{-1})								
0	0.001^{d}	0.0016^{d}	0.022^{d}	0.024^{d}	0.003^{d}	0.0013^{c}	0.02^{d}	0.02^{d}
13	0.003^{c}	0.018^{c}	0.025^{c}	0.030^{c}	0.004^{b}	0.013^{c}	0.03^{c}	0.03^{c}
26	0.016^{b}	0.023^{b}	0.034^{b}	0.041^{b}	0.004^{b}	0.018^{b}	0.04^{b}	0.04^{b}
39	0.017^{a}	0.033^{a}	0.040^{a}	0.044^{a}	0.007^{a}	0.042^{a}	0.05^{a}	0.06^{a}
SE ±(0.05)	0.0001	0.0003	0.0004	0.0003	0.0001	0.0004	0.001	0.001
Variety								
TGX 1985-10F	0.003b	0.02^{b}	0.03^{b}	0.04^{c}	0.004^{c}	0.02^{b}	0.03^{c}	0.04^{c}
TGX 1987-10F	0.005a	0.02^{b}	0.04^{a}	0.04^{c}	0.005^{b}	0.02^{b}	0.04^{b}	0.05^{b}
TGX 1448-2E	0.003b	0.02^{b}	0.03^{b}	0.03^{d}	0.004^{c}	0.02^{b}	0.04^{b}	0.04^{c}
TGX 1987-62F	0.005a	0.02^{b}	0.04^{a}	0.05^{b}	0.005^{b}	0.02^{b}	0.04^{b}	0.05^{b}
TGX 1989-19F	0.005a	0.03^{a}	0.04^{a}	0.06^{a}	0.006^{a}	0.03^{a}	0.05^{a}	0.06^{a}
TGX 1835-10E	0.003b	0.02^{b}	0.03^{b}	0.04^{c}	0.003^{c}	0.02^{b}	0.03^{c}	0.04^{c}
SE ±(0.05)	0.0002	0.0004	0.0005	0.0003	0.0002	0.0004	0.001	0.001

Means of different letter(s) in each column of treatment group are significant at 5% level of probability.

Conclusion

Dry matter production was enhanced significantly ($P<0.05$) by the application of phosphorus while TGX 1989-19F variety out-performed other varieties in this study. Phosphorus at 39 kg ha^{-1} produced significantly higher dry matter production while control plots produced significantly lower DMP of soybean plant at all growing stages in both 2018 and 2019 cropping years respectively. The observed variation in the performance of the soybean varieties in terms of dry matter production could provide a basis for selecting variety with high yielding ability. Thus, dry matter production is a reflection of higher yield in soybeans.

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